

## **CLAIMS**

What is claimed is:

- 1    1.    A method of determining a resistivity parameter of an earth formation using a  
2        logging tool within a borehole penetrating said earth formation, the method  
3        comprising:  
4        (a)    obtaining a plurality of first measurements with a resistivity sensor on the  
5               logging tool indicative of said parameter of interest at a plurality of  
6               rotational positions of the logging tool, said resistivity sensor having a  
7               substantially uniform azimuthal response characteristic; and  
8        (b)    determining said resistivity parameter from measurements made by said  
9               resistivity sensor at a position that is not at the center of said borehole.  
10
- 1    2.    The method of claim 1 further comprising:  
2        (i)    making second measurements with an orientation sensor indicative of a  
3               toolface angle of said logging tool at said plurality of rotational positions;  
4        (ii)    using at least one additional sensor to make third measurements indicative  
5               of said position of said logging tool relative to the center of said borehole  
6               at said plurality of rotational positions; and  
7        (iii)    determining from said second and third measurements said position of said  
8               resistivity sensor.  
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- 1 3. The method of claim 2 wherein said orientation sensor comprises a  
2 magnetometer.  
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- 1 4. The method of claim 3 wherein said magnetometer comprises a two-component  
2 magnetometer.  
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- 1 5. The method of claim 2 wherein said at least one additional sensor comprises two  
2 additional sensors.  
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- 1 6. The method of claim 5 wherein said at least two additional sensors comprise an x-  
2 and a y- component accelerometer.  
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- 1 7. The method of claim 2 wherein determining said position further comprises  
2 determining expected values of said third measurements at said plurality of  
3 rotational positions using said second measurements.  
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- 1 8. The method of claim 7 wherein determining said position further comprises  
2 determining differences between said third measurements and said expected  
3 values.  
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- 1 9. The method of claim 8 wherein determining said position further comprises  
2 performing an integration of said differences.  
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- 1 10. The method of claim 9 wherein said integration further comprises a double  
2 integration.  
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- 1 11. The method of claim 9 further comprising using a constraint for said double  
2 integration.  
3
- 1 12. The method of claim 11 wherein said constraint is based on a dimension of said  
2 borehole.  
3
- 1 13. The method of claim 11 wherein said constraint is based on a measurement made  
2 by a standoff sensor.  
3
- 1 14. The method of claim 1 wherein said resistivity parameter comprises at least one  
2 of (i) a position of a bed boundary in said earth formation, and, (ii) an orientation  
3 of a bed boundary in said formation.  
4
- 1 15. The method of claim 14 wherein determining said resistivity parameter further  
2 comprises defining a region in said earth formation to which said resistivity  
3 sensor is responsive independent of said position of said logging tool.  
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- 1 16. The method of claim 7 wherein determining said expected values further  
2 comprises using a sinusoidal curve fitting.  
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1 17. A measurement-while-drilling (MWD) tool for determining a resistivity  
2 parameter of an earth formation comprising:  
3 (a) a resistivity sensor having a substantially azimuthally uniform response  
4 function for making first measurements indicative of said parameter of  
5 interest at a plurality of rotational positions of the MWD tool;  
6 (b) an orientation sensor for making second measurements indicative of a  
7 toolface angle of said MWD tool at said plurality of rotational positions;  
8 (c) at least one additional sensor for making third measurements indicative of  
9 a position of said logging tool relative to a center of said borehole at said  
10 plurality of rotational positions; and  
11 (d) a processor for determining from said second and said third measurements  
12 said position of said logging tool.

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1 18. The MWD tool of claim 17 wherein said orientation sensor comprises a  
2 magnetometer.

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1 19. The MWD tool of claim 18 wherein said magnetometer comprises a two-  
2 component magnetometer.

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1 20. The MWD tool of claim 17 wherein said at least one additional sensor comprises  
2 an *x*- and a *y*- component accelerometer.

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1    21.    The MWD tool of claim 17 wherein said processor further determines expected  
2           values of said third measurements at said plurality of rotational positions using  
3           said second measurements.

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1    22.    The MWD tool of claim 21 wherein said processor further determines said  
2           position by determining differences of said third measurements from said  
3           expected values.

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1    23.    The MWD tool of claim 22 wherein said processor further performs a double  
2           integration of said differences..

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1    24.    The MWD tool of claim 17 further comprising a standoff sensor for determining  
2           an offset of the tool from a borehole wall.

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1    25.    The MWD tool of claim 17 wherein said processor determines said resistivity  
2           parameter based on said determined position.

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1    26.    The MWD tool of claim 25 wherein said resistivity parameter comprises at least  
2           one of (i) a position of a bed boundary in said earth formation, and, (ii) an  
3           orientation of a bed boundary in said formation.

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1     27.     The MWD tool of claim 25 wherein said processor further determines a region in  
2             said earth formation to which said resistivity sensor is responsive independent of  
3             said position of said logging tool.

1     28.     A system for determining a resistivity parameter of an earth formation  
2             comprising:

- 3             (a)     a bottom hole assembly (BHA) including a device for penetrating said  
4                     earth formation;
- 5             (b)     a conveyance device for conveying said BHA into said earth formation;
- 6             (c)     a resistivity sensor on said BHA having a substantially azimuthally  
7                     uniform response function for making first measurements indicative of  
8                     said parameter of interest at a plurality of rotational positions of the BHA;
- 9             (b)     an orientation sensor on said BHA for making second measurements  
10                    indicative of a toolface angle of said BHA at said plurality of rotational  
11                    positions;
- 12            (c)     at least one additional sensor on said BHA for making third measurements  
13                    indicative of a position of said logging tool relative to a center of said  
14                    borehole at said plurality of rotational positions; and
- 15            (d)     a processor on said BHA for determining from said second and said third  
16                    measurements said resistivity parameter.

17  
1     29.     The system of claim 28 wherein said orientation sensor comprises a two-  
2             component magnetometer.

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1 30. The system of claim 29 wherein said at least one additional sensor comprises an  
2 x- and a y- component accelerometer.

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1 31. The system of claim 28 wherein said processor further determines expected  
2 values of said third measurements at said plurality of rotational positions using  
3 said second measurements.

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1 32. The system of claim 31 wherein said processor further determines said position by  
2 determining differences of said third measurements from said expected values.

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1 33. The system of claim 32 wherein said processor further performs a double  
2 integration of said differences.

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1 34. The system of claim 28 wherein said processor determines said resistivity  
2 parameter based on said determined position.

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1 35. The system of claim 34 wherein said resistivity parameter comprises at least one  
2 of (i) a position of a bed boundary in said earth formation, and, (ii) an orientation  
3 of a bed boundary in said formation.

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1 36. The system of claim 28 wherein said conveyance device comprises a drillstring.

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- 1 37. The system of claim wherein said device for penetrating said earth formation  
2 comprises a drillbit.